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Transitions following the decay of Se^{75}

By MATHILDE DE CROËS[1] and GUNNAR BÄCKSTRÖM

With 5 figures in the text

ABSTRACT

The conversion electron spectrum and the gamma ray spectrum have been re-investigated by means of a double focusing spectrometer. Conversion coefficients have been determined relative to the 279 keV transition in Tl^{203}, mainly in order to investigate an EO admixture which according to previous works seemed to exist in the 264 keV transition. The multipolarity was however found to be pure M1, with a maximum EO admixture of 6×10^{-3}. The conversion coefficients generally support previous spin assignments. Transition energies also support all features of a published decay scheme. Two additional transitions have been found which are not accommodated by the known levels. An electron-gamma coincidence experiment was made in an attempt to locate these transitions.

Introduction

Se^{75} decays by electron capture, with a halflife of 127 days, to the stable isotope As^{75}. Many investigations have been made in the past of this decay, as well as that of Ge^{75} (82 min.) which also excites levels of As^{75}. An early permanent spectrograph study by Cork *et al.* [1] disclosed the existence of eleven transitions of energies up to 400 keV. Several years later, Schardt and Welker [2] reported a very comprehensive investigation of the levels of As^{75}, involving a study of both types of decay. The internal conversion spectrum was measured by means of a lens spectrometer set at a resolution of 3.2 % and the authors were able to verify by this method all, except two, of the transitions reported by Cork *et al.*, and conversion intensities could be given more quantitatively. The two additional transitions, of energies 25 keV and 81 keV, were seen in a recording with a semicircular spectrograph. Photoelectron lines from lead converters were recorded for some transitions, and these data, together with intensities from ordinary scintillation spectra, yielded photon intensities. Finally, normalization of the conversion and gamma intensities by a comparative measurement with a source of Cs^{137} provided absolute values for the conversion coefficients which permitted conclusions about multipolarity in many cases. The coincidence relationships between the gamma rays of Se were investigated by the use of two NaI(Tl) crystals with a multichannel device to record the coincident spectra. The beta spectrum of Ge was measured by means of an anthracene crystal, the single spectrum as well as components coincident with selected gamma rays. The combined information from these two sets of experiments was sufficient for the construction of a decay scheme including all known transitions. Levels were established at 199, 265, 280, 305 and 402 keV in As^{75} from the decay of Se^{75} and two additional levels, at 477 keV and 628 keV, were found to be excited in the negaton decay of Ge^{75}.

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[1] On leave of Université de Louvain, Héverlé-Louvain, Belgium.

Schardt and Welker also performed (γ, γ) angular correlation measurements on the two main cascades in the Se decay, and these results together with the multipolarities obtained from single spectra made possible a most probable, although not unique, assignment of spins and parities to the levels. Later angular correlation measurements by Kelly and Wiedenbeck [3] essentially confirmed these results without reducing the number of possibilities. Van den Bold *et al.* [4] re-investigated both decays by the use of scintillation techniques. The results of their very carefully performed gamma intensity measurements were somewhat at variance with those of earlier works and led to a different pattern of electron capture branching to the levels of As^{75}. Moreover, they succeeded in obtaining directional and polarization correlations of four cascades, and consequently new information on level parities became available. The authors were finally able to find a set of spins and parities which were in agreement with all existing data. This assignment is also unique, at least as far as concerns the levels excited in the Se decay.

A French group [5] reported to have observed a weak (0.04 %) gamma ray of 577 keV in the selenium decay. It may be interpreted as the ground state transition of a level observed in a Coulomb excitation experiment [6].

Metzger [7] recently reported a determination of the lifetime of the 265 keV transition by means of a resonance fluorescence experiment. The result for the total transition lifetime, $\tau = 2.5 \times 10^{-11}$ sec., in combination with available data [7] on the E2 lifetime ($\tau(\mathrm{E2}) > 10^{-9}$ sec.) indicated an almost pure M 1 multipolarity. In fact, taking the smaller of the two roots given by van den Bold *et al.* one obtains an E2 admixture of 3 %. This fact is however in definite conflict with the K-conversion coefficient experimentally obtained by Schardt and Welker. Their value is 0.016, whereas the theoretical K-conversion coefficient for M 1 is 0.0064.

It was the aim of the present work to investigate into the nature of this discrepancy. The effect would be of some interest if it were of a physical nature, in view of the obvious possibility of an admixture of EO multiplolarity in the 265 keV transition, which connects states of the same spin and parity (3/2 −). In order to make certain that no unknown feature of the decay had been present which could modify some conclusions of previous works, the internal conversion and photoelectron spectra of Se^{75} were investigated with the use of higher resolution than before. The conversion coefficient in question was measured by a method involving essentially a comparison with the well known transition from Hg^{203}.

Instrument. Source preparation

The conversion electron and the photo-electron studies reported here were all performed by means of a double focusing spectrometer of 50 cm radius [8]. By means of a rotating coil device, the field could be measured with an accuracy of $1:10^4$ on a relative scale.

Sources of Se^{75} were obtained by neutron irradiation in a pile at Oak Ridge. For the internal conversion measurements, sources of high specific acitvity (more than 5 C/g) were produced by the use of a target enriched in Se^{74}. It was obtained as a solution of H_2SeO_3, which was evaporated to dryness in a molybdenum crucible and vacuum deposited onto a thin (10 μ) aluminium strip, 2×15 mm^2. Two sources were provided, differing in their activity by an order of magnitude. With the stronger source, which had a strenght of about 500 μC, the conversion lines were considerably broadened because of electron straggling.

The source for the gamma ray measurements was produced by irradiation of natural selenium. About 30 mC of H_2SeO_3 was dissolved in alcohol, and the solution was evaporated dropwise into a cylindrical copper capsule, the walls of which were just sufficiently thick to stop the most energetic conversion electrons. It was possible to pack 20 mC of the activity into a quite small capsule, the outer diameter being 4 mm.

In a preliminary experiment for determining the conversion coefficients, a Hg^{203} source of low specific activity (~ 50 mC/g) was used, consisting of ordinary stock item activity, purchased from the Oak Ridge establishment. Later, a much thinner source was produced by irradiating mercury oxide, enriched to 90 % in Hg^{202}, in the DIDO reactor, Harwell. The irradiation lasted for a three week period and was made at a neutron flux of 10^{14}/cm^2 sec. The target was then converted to the chloride and evaporated in vacuo onto an aluminium backing.

Sufficiently strong and thin sources of Au^{198} were obtained by irradiation at a flux of 2×10^{12}/cm^2 sec at the reactor R1, AB Atomenergi, Stockholm. A source for internal conversion was prepared by vacuum deposition of the chloride onto a thin metal substrate on a mylar foil. The source of Au^{199} was prepared by irradiation of platinum, followed by chemical separation and vacuum deposition.

Internal conversion experiments

With the spectrometer set at a momentum resolution of 0.35 % the energy region 20 keV–500 keV was thoroughly and repeatedly scanned for conversion lines. Figures 1 and 2 show the conversion lines obtained with the stronger source.

Apart from the eleven transitions reported in previous works, two new transitions, of energies 188.40 keV and 203.0 keV, were discovered. Although the source had been purified by chemical separations,[1] by mass separation, and by distillation in vacuo, the presence of some element of higher cross-section could of course not be completely excluded. Furthermore, it is a remarkable fact that neither Cork *et al.* nor Schardt and Welker report these lines, although at least the stronger one should have been visible in their spectra, since it is comparable in intensity to the K-line of the 199 keV transition. However, the decay of the conversion lines in the region of 200 keV was followed for a period of more than six months, and the intensities of the new lines were found to remain accurately the same relative to that of K 199. To our knowledge, no long-lived isotope has been reported to emit prominent lines of these energies, and in spite of conflicting data it is necessary to assign the two new lines to the decay of Se^{75}.

As is seen in figures 1 and 2, the lines exhibit low energy tails because of source thickness, which also resulted in a varying resolution: 0.4 % at high energies, 0.6 % in the region of 100 keV, and 1.3 % at 25 keV. Intensity measurements were in general based on the spectra taken with this source. However, since the intensities were always determined by measuring the line areas, the varying resolution should intro-

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[1] A later spectrographic analysis by the Oak Ridge laboratory showed only traces of Mg and Si.

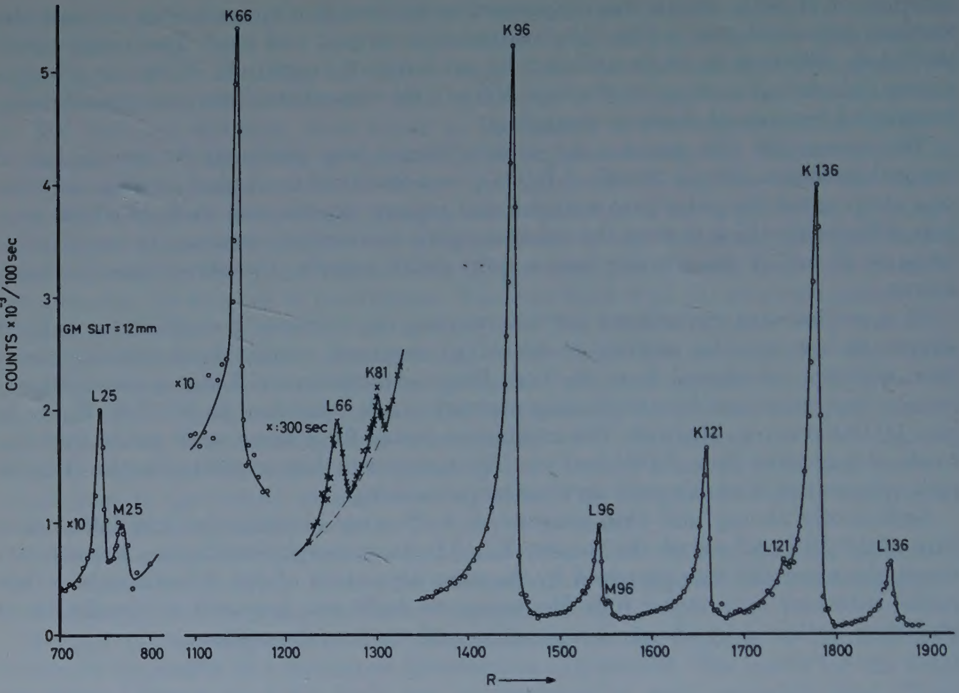

Fig. 1. Internal conversion spectrum, low energy part.

duce no error. The window of the Geiger tube, which was a mylar foil of thickness 0.9 mg/cm^2, caused appreciable absorption at the lower part of the spectrum. Correction for this effect was made by interpolation in the graphs of Lane and Zaffarano [9]. The uncertainty of this correction is estimated at 30 % for the L line of the 25 keV transition. The K-conversion intensities are given in table 1 together with those reported by Schardt and Welker.

Energy calibration was furnished by sources of Au^{199} and Au^{198}, both of which contain lines of well known energies [10], and these standard lines lie quite close to some strong lines in Se^{75}. Energy determinations were made by introducing the selenium source and the standard sources one after the other into the spectrometer. The selenium line K 96 was measured against the 75 keV conversion line from Au^{199}, the line K 136 against the 125 keV line in the same gold source, and K 304 against the nearby K line of the 412 keV transition from Au^{198}. The source positions could be reproduced to within 0.1 mm, and the error introduced by this uncertainty was negligible. The method that was used in order to reproduce accurately the source position is perhaps worth mentioning. Sources were mounted on aluminium rings, which fitted closely into a circular identation into the flat tip of the source-holder rod. While the position of the rings could thus be reproduced within 0.01 mm, if necessary, the positioning of the radioactive distribution into the centre of the ring is a considerable problem. This difficulty was overcome by recording each line twice, the source ring being turned by 180° between the runs. The momentum determination

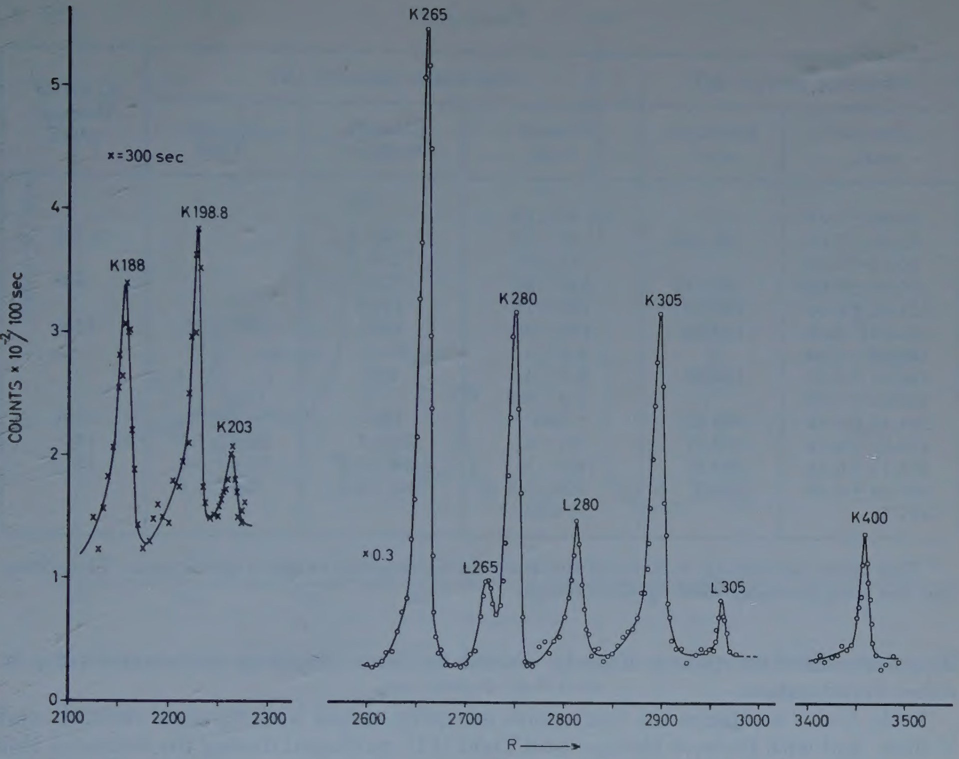

Fig. 2. Internal conversion spectrum, high energy part.

was simply made on basis of the mean position of the lines so obtained. It is believed that this procedure is necessary in comparative measurements of line energies at high precision.

It would have been difficult to measure lines from a thick source against standard lines which showed no thickness effects, and therefore the weaker selenium source was used for these calibrations. With the resulting low counting rates it was only possible to measure the strongest lines. However, the energy of the weaker lines could be obtained quite accurately by interpolation in the spectra obtained with a stronger source. A check on the energy of the 400 keV transition was obtained in a photo-electron experiment with a source of Au^{198} (412 keV). The final values of the transition energies are summarized in Table 1. The energy data are listed together with the results from a curved crystal investigation by Edwards, Gallagher Jr., and Dumond [11], which appeared in print during the course of this work. The results of these authors are somewhat at variance with those of the present work. It is noticed that, although the agreement is quite satisfactory on a relative scale, the absolute energy values of Edwards *et al.* are higher by about one part in 10^3. The deviation is in the direction to be expected if it were caused by self-absorption in our selenium sources. The magnitude of the deviation can, however, not be explained by such an effect and the explanation does not at all apply to the photo-electron experiment.

Table 1.

Transition energy, keV		Conversion intensity (K)			$K/L+M$ Present work
Present work	Edwards *et al.*	Present work	Schardt, Welker	Metzger, Todd	
24.48 ± 0.07		L: 45 ± 13			
65.98 ± 0.10	66.054	80 ± 12	67		$\simeq 3.5$
80.75 ± 0.10		14 ± 3	$\simeq 8$		
96.70 ± 0.03	96.741	940 ± 60	710		8.6
121.02 ± 0.04	121.12	180 ± 12	173		
135.89 ± 0.03	135.99	450 ± 30	420	377 ± 20	11.4
188.40 ± 0.20		6.2 ± 1			
198.55 ± 0.20	198.60	6.8 ± 1	6.5		
203.02 ± 0.20		1.0 ± 0.2			
264.42 ± 0.13	264.62	100	100	100	10.8
279.22 ± 0.14	279.57	63 ± 5	53 ± 7	53.6 ± 1.6	11
303.71 ± 0.15	304.0	16.0 ± 1	15.6 ± 1.3[a]	15.4 ± 0.9	12
400.34 ± 0.20	400.7	3.8 ± 0.3	3.6 ± 0.6	3.6 ± 0.4	
(467.7)		< 0.04			

[a] This value deviates by a factor of two from the figure given in the original paper. The correction has been communicated by the authors.

Therefore, the discrepancy must be caused by some unknown systematic error in either investigation.

Table 1 also compares the conversion intensity values with those of Schardt and Welker, and with those of Metzger and Todd [12], published during the course of this work. The agreement is reasonably good, except with the intensity of the line K 136, for which Metzger and Todd report a lower value. These authors used an anthracene crystal, and it is not impossible that the broad pulse distribution produced at 125 keV electron energy may have caused this loss in efficiency. The present work yields new data for the intensities of the lines L 25 and K 81. The $K/L+M$ ratios listed in the last column are given, not because they contribute to the knowledge of multipolarity, but because their consistency with theory indicates that the L and M groups are pure and do not mask any unknown K-line.

Photo-electron experiments

It was possible, by means of the 20 mC source, to measure the photo-electron lines of six transitions at a resolution of about 1 %. Most of the experiments were made with a lead radiator of size 4×20 mm^2 and with a thickness of 1.5 mg/cm^2. Parts of the spectrum is shown in figures 3 and 4. The main objective for recording the photo-electrons was to determine the relative intensities of the 264 keV and 279 keV transitions, required for a conversion coefficient determination. However, it is possible to determine other gamma intensities as well if the radiator efficiency is known as a function of energy. The total photo-electric cross-section is well known, both theoretically and experimentally. The angular distribution of the electrons from uranium has been measured experimentally by Hultberg [13] at all angles and at three energies. Using his tabulated values of the differential cross-section, Marklund,

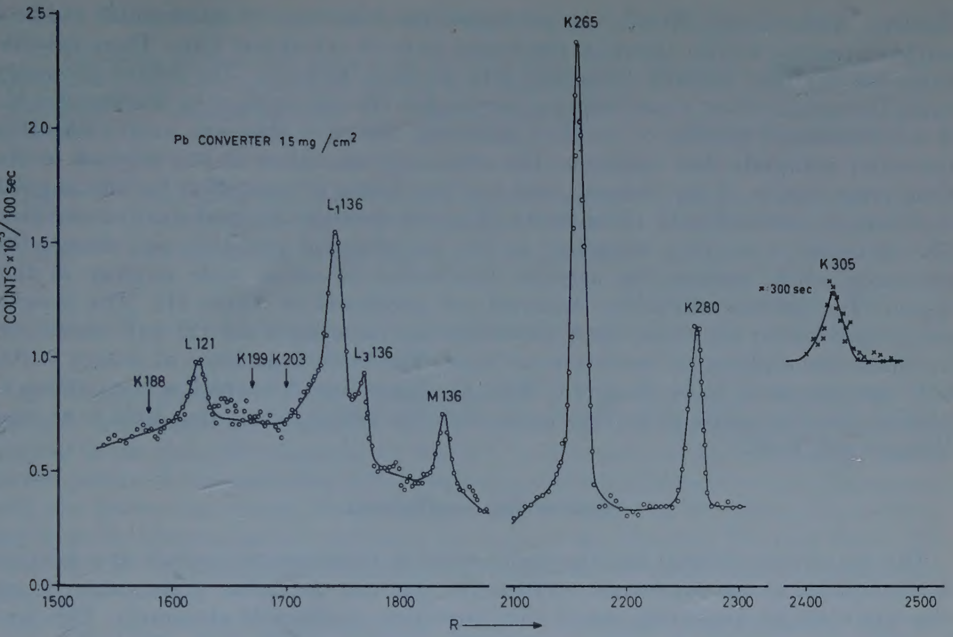

Fig. 3. Photo-electron spectrum from a lead radiator. The *K* lines of the 0.2 MeV transitions are just masked by *L*-lines.

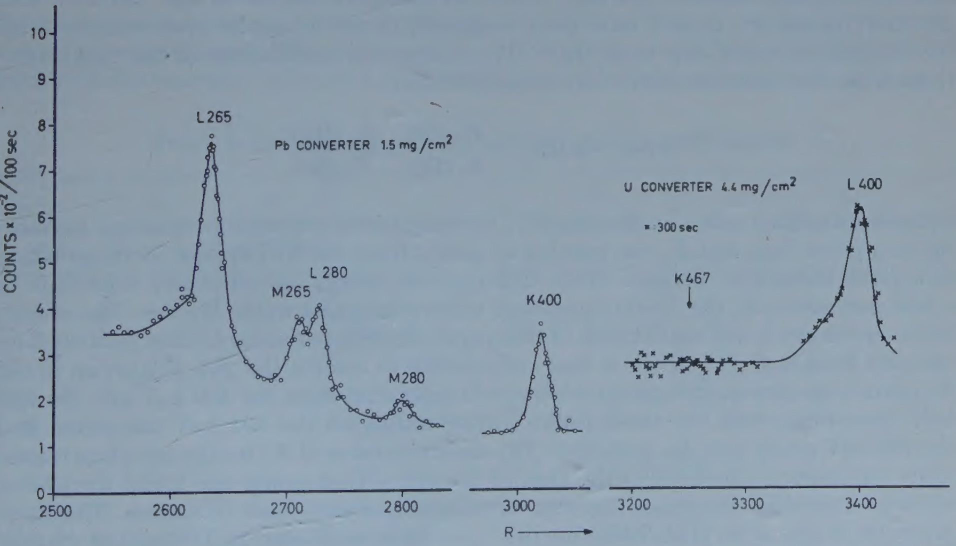

Fig. 4. High energy part of the photo-electron spectrum. A lead radiator was used, except in searching for a possible 467 keV transition.

Nathan, Nielsen, and Wood [14] calculated the efficiency of rectangular radiator strips of various widths, assuming the source to be of cylindrical form. These calculations did not take electron straggling into account, however. The source geometry being the same in these experiments as assumed in the calculations by Marklund *et al.*, it was considered possible to use their efficiency curves in this case, even with other converter materials than uranium. The efficiency was taken as the product of the total cross-section of the element used and the factor of correction for the angular distribution, assumed to be the same for all heavy elements at equal electron energies. The inclusion of electron straggling at low energies will probably not change the efficiency much, because the angular distribution is rather wide anyway in this region. The gamma intensities obtained are presented in Table III. The lowest-energy gamma ray for which the K photo-line was recorded is the 121 keV transition, in which case a platinum converter was used. The three transitions of energy ~200 keV were too weak to be observed. With the transitions for which a comparison is possible, the intensities given here agree with the values of van den Bold *et al.* and Metzger and Todd.

Conversion coefficients

The conversion electron and the photo-electron measurements result in a relative determination of the conversion coefficients. One can normalize these values to an absolute scale by measuring one of the conversion coefficients absolutely. This was done by comparison to the known conversion coefficient [15] of the 279 keV transition in Tl^{203}.

A thin source of Hg^{203} was prepared by vacuum deposition, the size being the same as for the selenium deposit. Scintillation spectra were taken, with a $1\frac{1}{2}'' \times 1\frac{1}{2}''$ NaI(Tl) crystal, for both the Se^{75} and the Hg^{203} activity. Care was taken to reproduce the source-to-crystal distance (30 cm). The conversion intensities of the 264 keV and 279 keV transitions in Se^{75} were then compared in the magnetic spectrometer with the intensity of the K-line from Hg^{203}. The conversion coefficients for the two transitions from the selenium source are obtained from

$$\alpha(\mathrm{Se}) = \alpha(\mathrm{Hg}) \times \frac{N_e(\mathrm{Se})}{N_e(\mathrm{Hg})} \times \frac{N_\gamma(\mathrm{Hg})}{N_\gamma(\mathrm{Se})}$$

where α:s are conversion coefficients, N_e the number of conversion electrons pertaining to a given line, and N_γ the number of pulses from the NaI crystal, corresponding to a given transition. Because of the difference in energy, an efficiency correction of a few per cent to N_γ (Se, 264) is necessary when comparing to the Hg line. The scintillation spectrum is not reproduced in this paper, since it is similar to that published by van den Bold *et al.* [4]. While it was not possible to resolve the 264–279 group in the Se gamma spectrum, this group is very well separated from the 400 keV and the 136 keV transitions, and the small peaks corresponding to the 304 keV transition and the 200 keV group may be neglected. The determination of N_γ for the selenium transitions was made by measuring the area of the unresolved group and using the photo-electron intensities for separating the contributions due to each transition. The value given by Neigh *et al.* [15] (1958) for the conversion coefficient in Tl^{203} $(0.163+0.003)$ was used in the above formula. The results are found in Table 2, where the values obtained for the individual ratios have been included.

Table 2. Results of the determinations of conversion coefficients.

The errors given do not include the errors in the primary conversion coefficients.

Reference source	Gamma intensity ratio	Electron intensity ratio	Conversion coefficient
Hg^{203}	Se 279/Hg 279 = 5.13 Se 264/Hg 279 = 12.1	Se 279/Hg 279 = 0.313 Se 264/Hg 279 = 0.494	$\alpha\,(279) = (9.9 \pm 1)\ 10^{-2}$ $\alpha\,(264) = (6.6 \pm 0.7)\ 10^{-3}$
Au^{198}	Se 400/Au 412 = 0.218	Se 400/Au 412 = 0.0088	$\alpha\,(400) = (1.12 \pm 0.1)\ 10^{-3}$ $\alpha\,(279) = (1.02 \pm 0.15)\ 10^{-3}$ $\alpha\,(264) = (6.9 \pm 1)\ 10^{-3}$

As an indirect check on the determination of the conversion coefficients, the 400 keV transition was measured for the conversion line and gamma ray intensity relative to the pure E2 transition of 412 keV in the decay of Au^{198}. Although recent investigations of this and other E2 conversion coefficients [16] show some discrepancy with the theoretical values, these may probably be relied on to within 15 % or 20 %, and thus the determination was made on basis of the tables of Sliv and Band. The result of the experiment, given in Table 2, indeed agrees quite well with that of the alternative method.

All the conversion coefficients that could be obtained from available data are listed in Table 3 together with the theoretical values for possible multipolarities.

Coincidence experiments

An attempt was made to determine the location of the 188 keV and the 203 keV transitions in the decay scheme. By the use of a circular source, cut out of the strip source previously used, the electron-gamma coincidences were investigated with a thick lens spectrometer [17] and a 2″ NaI(Tl) crystal. In this particular case a momen-

Table 3. Gamma intensities and conversion coefficients.

E_γ	I_γ Present work	I_γ von den Bold *et al.*	I_γ Metzger and Todd	Conv. coeff.	E_1	M_1	E_2	M_2	E_3	M_3
4.48	—	—	—	—	—	—	—	—	—	—
5.98	—	2.1 ± 0.8	—	2.6×10^{-1}	*$2.3\ 10^{-1}$*	*$2.6\ 10^{-1}$*	3.0	—	—	—
0.75	—	—	—	—	—	—	—	—	—	—
6.70	—	5.8 ± 0.6	—	1.1	—	—	$7.6\ 10^{-1}$	$9.2\ 10^{-1}$	6.4	—
1.02	28 ± 5	24.5 ± 3	—	$(4 \pm 0.8)\ 10^{-2}$	*$3.6\ 10^{-2}$*	*$4.7\ 10^{-2}$*	$3.3\ 10^{-1}$	$4.2\ 10^{-1}$	—	—
5.89	86 ± 15	76 ± 5	—	$(3.3 \pm 0.6)\ 10^{-2}$	*$2.6\ 10^{-2}$*	*$3.5\ 10^{-2}$*	$2.1\ 10^{-1}$	$2.8\ 10^{-1}$	—	—
8.40	—	—	—	—	—	—	—	—	—	—
8.55	—	3.6 ± 0.4	—	1.3×10^{-2}	*$8.6\ 10^{-3}$*	*$1.3\ 10^{-2}$*	$5.2\ 10^{-2}$	—	—	—
3.02	—	—	—	—	—	—	—	—	—	—
4.42	100	100	100	$(6.6 \pm 0.7)\ 10^{-3}$	$3.8\ 10^{-3}$	*$6.3\ 10^{-3}$*	$1.9\ 10^{-2}$	—	—	—
9.22	42.5 ± 2	52 ± 5	47 ± 1	$(9.9 \pm 1)\ 10^{-2}$	—	*$5.6\ 10^{-3}$*	*$1.6\ 10^{-2}$*	—	—	—
3.71	2.15 ± 0.3	—	2.1 ± 0.3	$(5.0 \pm 0.7)\ 10^{-2}$	—	—	—	—	*$4.5\ 10^{-2}$*	*$5.5\ 10^{-2}$*
0.34	23 ± 2	28 ± 2	19 ± 2	$(1.1 \pm 0.15)\ 10^{-3}$	*$1.2\ 10^{-3}$*	$2.3\ 10^{-3}$	—	—	—	—

tum resolution of 7 % was obtained for the electrons at a transmission of about 1.5 % of the sphere. At this resolution it was not possible to resolve the group *K* 188–*K* 199–*K* 203, while this group was very well separated from lines of other transitions. In the NaI crystal the transitions of 264 keV and 279 keV produced a composite peak, containing negligible contributions from other lines. The compton distribution from this thick crystal was also very small.

A test on the performance of the arrangement was made by taking coincidences between the 264–279 keV peak in the scintillation crystal and the conversion line of the 136 keV transition, which was sufficiently well separated from other lines. This experiment resulted in 330 coincidences per 300 sec, the accidental counts being negligibly few at the resolution time used ($2\tau = 4 \times 10^{-8}$ sec). This result reflects the previously known fact that the transitions 136 keV and 264 keV form a cascade. A coincidence measurement was then made between the same scintillation peak as before and the conversion line group at about 200 keV. According to the level scheme of Schardt and Welker, there should be no coincidences between the *K* 199 component and the scintillation peak, and thus a net coincidence effect would indicate a level at about 470 keV. In two experiments, lasting each 10^4 sec, the number of coincidences amounted to 56 counts and 64 counts respectively. However, when a similar experiment was made, the beta spectrometer focusing the background near the line group, an effect of 29 true counts still remained. As a further difficulty, the recorded number of coincidences is lower by an order of magnitude than the number calculated on basis of the test experiment, assuming *K* 188 to be coincident with the 279 keV transition. The half-lifes of the intermediate levels are sufficiently short [5] not to cause any coincidence loss. The conclusion must be that the 188 keV transition is not in coincidence with 264 keV or 279 keV, and the same situation exists with the 203 keV transition, although here the result is not equally definite. The nature of the observed small coincidence effect is at present not understood.

Conclusions

The transition energies obtained are in good agreement with the decay scheme proposed by Schardt and Welker [2]. From an investigation of cross-over relations ($E_1 + E_2 = E_3$) it was found that, within the limits ± 1 keV, there exists seven relationships, all of which are accounted for by the decay scheme. The mean energy deviation in these seven cases was 0.08 keV. It is interesting to note that, apart from a reversal of the whole pattern, the numerical relationships lead uniquely to this level scheme, as may be shown by a topological analysis. The ambiguity is removed when the intensity balance is considered. The energy support for the location of the transitions of 24 keV and 81 keV is especially important, since coincidence data have failed to reveal their position.

The two new transitions are not accounted for by the reported levels in the selenium decay. Their energy difference is, however, accurately equal to the difference between the second and third excited states, and therefore a new level at either 468 keV or 76 keV suggests itself. A level of 470 keV has been reported by Schardt and Welker in the decay of Ge^{75}, and the new lines detected here could possibly de-excite this state. That this is not the case may be shown by comparing the gamma ray branching in both types of decay. Assuming the 470 keV, 468 keV levels to be identical, the level spin has to be low, say 5/2 or less, because of the observed feeding from Ge^{75} ($\frac{1}{2}-$).

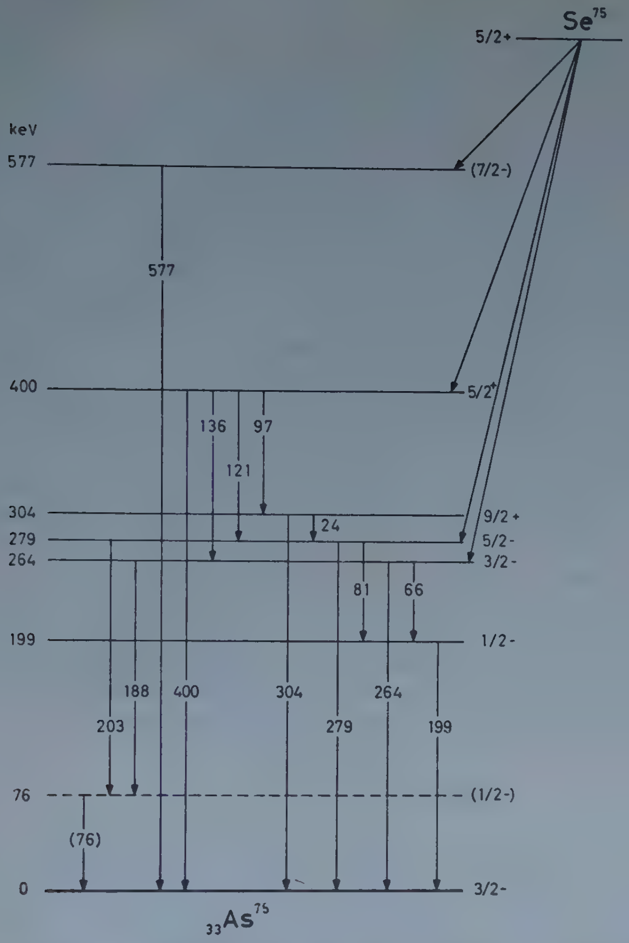

Fig. 5. Decay scheme of Se^{75} according to Schardt and Welker, with the addition of a level reported by Langevin–Joliot and Langevin [5].

The values within brackets are gamma intensities. A plausible way of accounting for the additional transitions of the present work is illustrated to the left. Spin and parity assignments are mainly due to van den Bold *et al.*, the spin of the new level at 76 keV being suggested such as to satisfy elementary selection rules. The possible weak M1 transition emitted from the 199 keV level to this new state may well be hidden in the spectrum between K 121 and L 121. Further data presented in this paper support the decay scheme in general.

Consequently, the transitions of 188 keV and 203 keV are of low multipole order (quadrupole or lower), and their gamma intensities may be estimated. For the level observed in the germanium decay one has $I_\gamma(470)/I_\gamma(188) > 0.2$ whereas the same ratio in the selenium decay becomes less than 10^{-3}, if the upper limit for the intensity of the 468 keV transition is taken from van den Bold *et al.* The additional transitions of 188 keV and 203 keV accordingly do not originate from any known level. The coincidence experiments show that they are not coincident with the 264–279 keV combination and consequently could not depopulate a level at 468 keV. The only remaining alternative which accounts for both lines is a level at 76 keV. There is indeed some evidence for a transition depopulating this level. Its K conversion line would coincide in energy with L 66, and this line is really far too intense, considering the dipole character of the 66 keV transition, which requires a K/L ratio of about 10. The data accordingly support the existence af a level at 76 keV.

As seen from Table 3 there remains no anomaly in the conversion coefficient of the 264 keV transition. Within the limits of error, the conversion coefficient equals that of a pure M1 transition, in agreement with the multipole assignment inferred from life-time measurements [6, 7]. An upper limit of about 6×10^{-3} may be given for any electric monopole contribution to this transition.

The conversion coefficient of the 279 keV transition yields an assignment of M1 with a strong admixture of E2 (40 %), a result which is not in conflict with the spin values assigned. The 304 keV transition is evidently of octupole character, from which it is concluded that the spin of the isomeric state is 9/2. Even parity for the 400 keV level is the consequence of the doubtless E1 multipolarity of the ground state transition. The dipole assignment obtained for the transitions of 66, 121, 136, and 199 keV support the spin assignments in so far as the spin difference indeed never exceeds unity.

No multipolarity determination could be made for the 24 keV transition. According to its location and the spin assignment it should be of M2 character. One manner of checking this point is to compute its radiative life-time on the basis of the measured life-time of the 304 keV level, using the appropriate conversion coefficient to compute the gamma intensity of the 24 keV transition (yielding $I_\gamma = 0.011$).Taking $\tau = 0.02$ sec for the mean lifetime [18] leads to a value for the expression

$$\log_{10}[\tau_\gamma A^{\frac{2\Delta I-2}{3}} E^{2\Delta I+1}] = -4.5$$

which falls into the middle of the region of M2-transitions according to the systematics of Goldhaber and Sunyar [19]. A different assumption concerning the conversion coefficient would not influence the above value so much as to introduce ambiguity.

Finally it should be noted that the set of spins and parities proposed by van den Bold *et al.* account quite satisfactorily for the measured gamma ray branching from the levels. One could possibly expect to observe the M2 transition connecting the 400 keV and 199 keV states, but the K conversion line would be located between the lines K199 and K 203 and may be masked by these lines. In conclusion, all the data emerging from the present investigation support the level scheme and the spin assignments due to Schardt and Welker and to van den Bold *et al.*

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